VLF Reception on the PC

antenna on the soundcard

By H. Lutz

In the past, reception of utility stations at the low end of the radio spectrum typically required a suitable receiver or up-converter. Today, things are much simpler — just use a PC soundcard and a lot of wire.

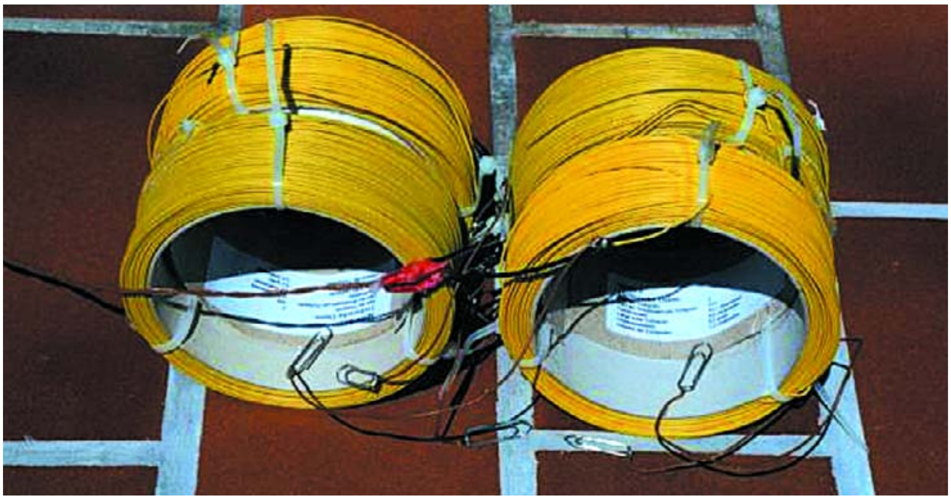


Figure 1. A receive-only antenna for the very low end of the VLF band.

Any reasonably modern PC (Pentium 100 running Windows 95 or later) with a soundcard can be turned into a radio receiver for frequencies below 24 kHz (VLF range). This is possible without costly hardware or software additions. The only hardware you need to get your hands on is a suitable antenna. In the software department, all you need is a spectrum analysis program which is available free of charge.

Antenna

As on the medium and long wave bands, VLF (very low frequency) reception typically requires a inductive antenna. For best results, such an antenna should consist of an inductor with a large cross section and/or a large number of turns. In the case of a receive-only antenna, electrical properties like inductance and ohmic resistance are relatively unimportant factors and therefore allowed to vary over a large range. Consequently, constructing such an antenna is relatively easy. All you need is a reel of light-duty isolated wire which is connected to the LINE or MIC input of the soundcard via a piece of 2-wire cable with a length of at least 2 metres.

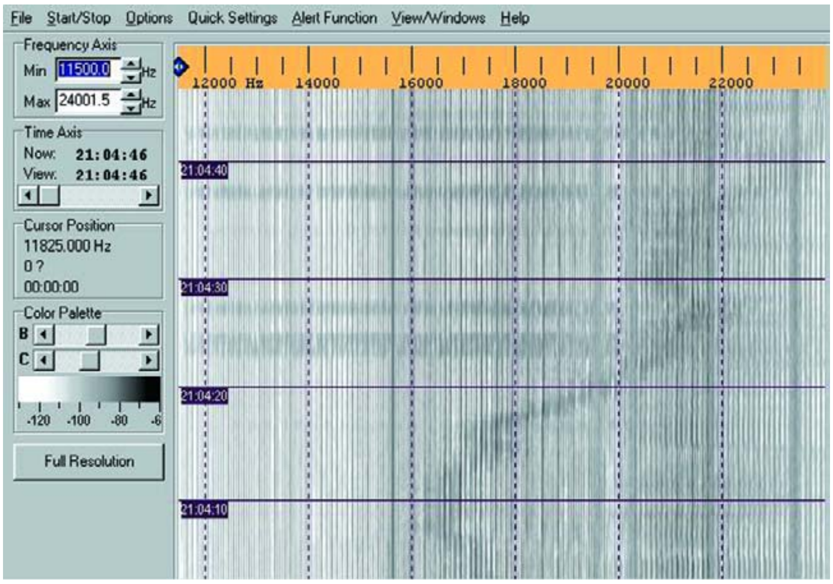
For best results, a minimum distance of about 2 metres should be observed between the antenna coil and the PC (and other electronic equipment). The antenna coil should be in a horizontal position. In steel-concrete buildings a position near a window is the best choice.

To improve our receiver's sensitivity, several antenna coils may be connected in series. The direction of the windings should be the same on all coils. If not, induced signals will cancel each other.

Figure 1 shows a VLF receiving antenna consisting of four series-connected wire reels of which two point in the same direction. Each wire reel has a diameter of 10.3 cm and consists of 309 turns. Paperclips allow individual wire reels to be shorted out for experiments.

Soundcard input

After connecting the antenna to the soundcard input, you will need to select the signal source on the PC. Right-click on the loudspeaker symbol in the far end of the task bar. Alternatively (in Windows 98), select Programs -> Accessories -> Entertainment -> Volume Control. If necessary, uncheck 'Mute' for the input to which the antenna is connected, and move up the 'recording volume' slider. Confirm the settings by click-



Frequency Axis
Min 11500.0 Hz
Max 24001.5 Hz

Time Axis
Now: 21:04:46
View: 21:04:46

Cursor Position
11825.000 Hz
0 ?
00:00:00

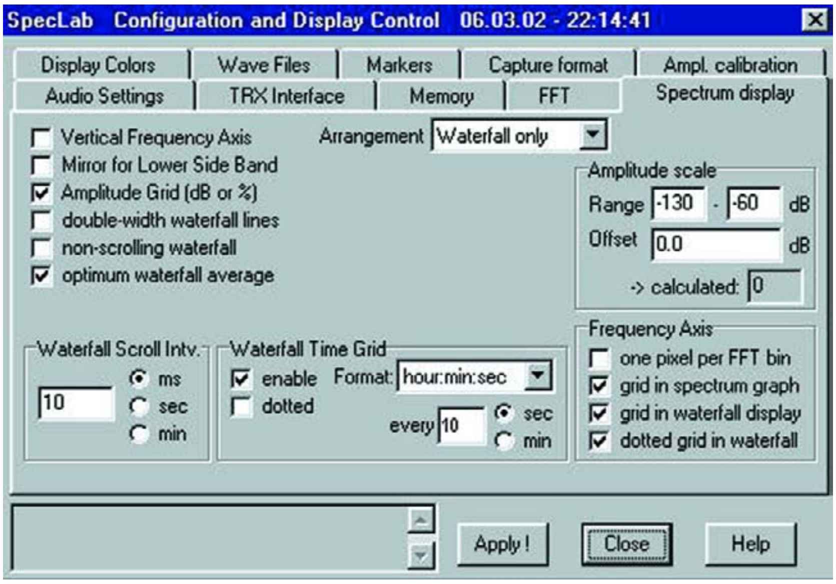
Figure 2. Main window shown by the SpecPlus software.

ing on 'OK'. The volume control slider for VLF reception should be set to maximum, and the balance control to the centre position. Naturally, these settings may be changed later, for example, if a spectral analysis of a different signal is required.

Analysis software

Several programs are available for spectral analysis of low-frequency signals applied to the PC via the soundcard (see www.vlf.it/harald/strangerec.htm).

The author only uses the extremely powerful software called **SpecPlus**, mainly because it is capable of storing received signals in the form of jpeg files containing frequency/time/intensity diagrams (also known as 'spectrograms'). The main window presented by SpecPlus is shown in **Figure 2**. This filter is marked by excellent stability under Windows 95, Windows 98 and Windows ME. No information is available about the performance of SpecPlus under Windows NT or later Windows versions. We know for sure, however, that the program will not run under Windows 3.x.



SpecLab Configuration and Display Control 06.03.02 - 22:14:41

☐ Vertical Frequency Axis
☐ Mirror for Lower Side Band
☑ Amplitude Grid (dB or %)
☐ double-width waterfall lines
☐ non-scrolling waterfall
☑ optimum waterfall average

Arrangement: Waterfall only

Amplitude scale
Range -130 - -60 dB
Offset 0.0 dB
-> calculated: 0

Waterfall Scroll Intv.
10
● ms
○ sec
○ min

Waterfall Time Grid
☑ enable
☐ dotted
Format: hour:min:sec
every 10
● sec
○ min

Frequency Axis
☐ one pixel per FFT bin
☑ grid in spectrum graph
☑ grid in waterfall display
☑ dotted grid in waterfall

Figure 3. Configuration screen for the spectrum analyser.

SpecPlus is available as a free download from www.qsl.net/dl4yhf/spectra1.html Having downloaded the .zip file, you first unpack it in an installation directory using WinZip. Next, the software may be installed. In line with results obtained from practical experience, the software should run without problems.

With the program up and running, you need to look at some settings. First, determine the colour palette. Although many simulated colour settings are a sight for sore eyes, the preferred colour setting for the readout is black for the signals and white for the background. After all, this combination is easily understood even without knowledge of the colour palette. Besides, the resultant jpeg files may be compressed further using other programs, without losing information or creating room for errors or confusion due to wrong or badly combining colours appearing in the end result.

To define the colour palette, a file with certain settings may be loaded via the Configuration menu (**Figure 3**), using 'Option' and then 'Load Colour Palette'.

Next, set the sampling rate using 'Option' and then 'Audio Settings'. The sampling rate determines the highest frequency that can be received, as follows:

f = sampling rate / (2-input Sample Rate Divisor).

For a maximum input frequency of 24 kHz (most inexpensive soundcards are unable to process higher frequencies) the sampling rate should be set to 48 kHz and the 'Input Sampling Rate Divisor' to 1.

Next, it's time to have a look at the FFT characteristics. Go to 'Options' then 'FFT Settings'. For reception of VLF signals, 'FFT Output' should be set to 'Logarithmic', and 'FFT type' to 'Real number FFT starting at 0'.

The next setting concerns the readout mode. Go to 'Options', 'Display', 'Spectrum Display Settings', and select a display range of –60 to –130 dB.

In practice this range was found to be the most useful for meaningful displaying of VLF signals. Stronger signals should not be expected while the noise level of the average sound card is typically at –120 to –130 dB. In the same window, further settings may be defined for the way results are displayed on your monitor (see illustration).

Finally, in the main window, you need to set the two sliders B (Brightness) and C (Contrast) for optimum sensitivity. This is done by disconnecting or short-circuiting the antenna and moving the B slider so that a white background just remains visible. The Contrast slider C is then moved so that small intensity variations can be seen. For fine adjustment, reconnect the antenna. Because the B and C adjustments affect one another it may be necessary to repeat the above procedure several times until you are satisfied with the resulting display.

At this point your PC is ready to be used as a VLF band receiver.

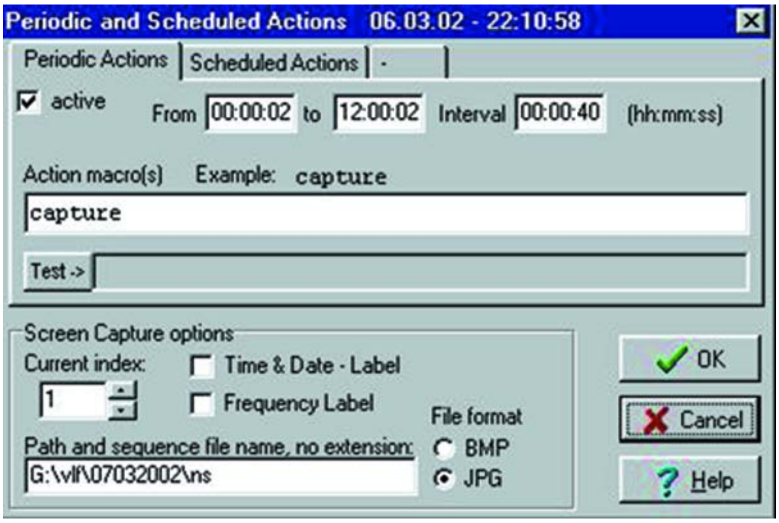
Because PC monitors generate strong interference in the VLF range, it is recommended to record a spectrum with the monitor switched off, save the file and view it later. Time controlled automatic operation with the monitor switched off is therefore the best mode to use. Practical experience has established the hours between 00.00 h and 06.00 h to be the best for VLF reception, not so much with propagation conditions in mind, but because interference levels due to electrical appliances are then at their lowest.

Automatic operation is possible by selecting 'File' and then 'Periodic Actions' (**Figure 4**). The settings shown here cause one spectrogram graphic to be stored every 40 seconds under the file designation

ns + consecutive number + .jpg

between 00:00:02 h and 12:00:02 h and written into the directory g:\vlf07032002.

The two letters at the start of each file name indicate the axis of reception; '*ns*' meaning north-south, '*ew*' , east-west. This is useful because the antenna used is directive. Make sure the desired directory exists and that 'Active' is checked (enabled) because otherwise no recordings are made.


Periodic and Scheduled Actions 06.03.02 - 22:10:58

☑ active From 00:00:02 to 12:00:02 Interval 00:00:40 (hh:mm:ss)

Action macro(s) Example: capture

capture

Screen Capture options

Current index: 1

☐ Time & Date - Label

☐ Frequency Label

File format ○ BMP ● JPG

Path and sequence file name, no extension: G:\vlf\07032002\ns

Figure 4. Automatic operation of SpecLab.

Received signals

The VLF range contains dozens of signals from various origins. Many signals that can be picked up originate from colossal transmitter sites and have travelled a long way to your antenna. Other signals are from nearby sources in and around your own home. A number of stations that can be received at reasonable quality in west and central Europe are listed in **Table 1**. In the frequency range 10 to 24 kHz, you'll find military operated VLF stations transmitting surfacing commands and other simple messages to submarines. The penetration depth of VLF radio signals in sea water is of the order of 10-30 metres, depending on the frequency used, receiver sensitivity, distance travelled over land, water temperature and salinity.

The same frequency range also contains navigation and time standard signals. Despite its favourable

Callsign	Frequency	Location	Note(s)
-	11.905 kHz	Russia (various locations)	ALPHA Navigation
-	12.649 kHz	Russia (various locations)	ALPHA Navigation
-	14.881 kHz	Russia (various locations)	ALPHA- Navigation
?	15.8 kHz	?	
GBR	16.0 kHz	Rugby	
JXN	16.4 kHz	Helgeland (Norway)	
SAQ	17.2 kHz	GGrimeton (Sweden	Special occasions only
?	17.8 kHz	Cutler, ME? (USA)	
RDL/UPD/UFQE/UPP/UPD8	18.1 kHz	Russia (various locations)	
HWU	18.3 kHz	Le Blanc (France)	Often off the air for long periods
RKS	18.9 kHz	Russia	Rare and brief activity
GBZ	19.6 kHz	Criggion	Several different modes
ICV	20.27 kHz	Tavolara (Italien)	
RJH63/RJH77/RJH99 u.a.	20.5 kHz	Russia (various locations)	Time signals
ICV	20.76 kHz	Tavolara (Italy)	
HWU	20.9 kHz	Le Blanc (France)	
RDL	21.1 kHz	Russia (various locations)	Rare and brief activity
HWU	21.75 kHz	Le Blanc (France)	
RJH63/RJH77/RJH99,u.a.	23.0 kHz	Russia (various locations)	Time signals
DHO38	23.4 kHz	West-Rhauderfehn (Germany)	
NAA	24.0 kHz	Cutler (USA)	

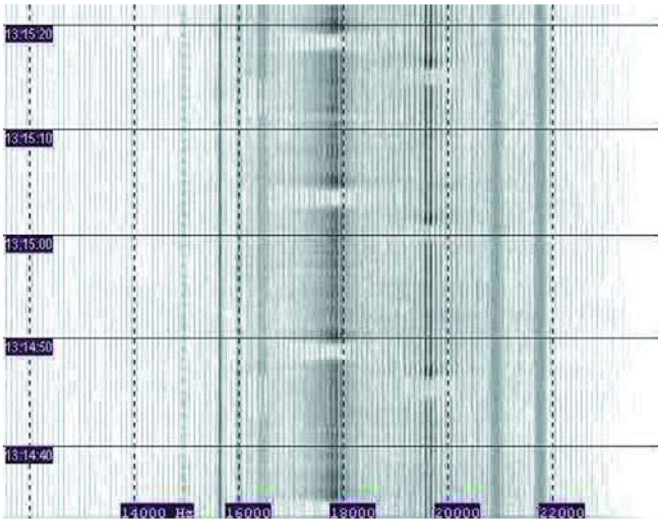


Figure 5. Example of a VLF spectrum showing some signals and interference.

propagation characteristics (enabling permanent worldwide communication) the 10-24 kHz section of the VLF band is not used for broadcast or other 'civil' applications, mainly because of the enormous size of the antennas (whose footprint are larger than the state of Monaco) and the extremely limited bandwidth of just 100-300 Hz. Most transmissions from the military are encoded using high-level encryption methods and will be impossible to decipher.

That leaves you with the challenge of investigating and recording the transmission times of the various stations (no VLF station except ALPHA Navigation is on the air around the clock), examine the intensity and the shape of the received signals, or determine their approximate direction. Directional finding involves performing a 'minimum' signal strength measurement using a ferrite or a window antenna.

The best noticeable signals in the VLF range originate from Navy transmitters. Most of these employ an encoded MSK mode and bandwidths between 100 Hz and 200 Hz.

In the spectrograms, MSK signals are identified as solid lines whose thickness is a measure of the bandwidth. **Figure 5** shows frequency-modulated burst signals from JXN, GBZ and an unidentified station at 17.8 kHz (possibly Cutler, ME, a US Navy station, *Ed.*). You will also notice MSK signals from HWU at 20.9 kHz and 21.7 kHz, as well as GBR (Rugby) at 16 kHz.

The line at 15.625 kHz indicates radiation of the horizontal line frequency component from a nearby TV set. The signal at 14.8 kHz is cheerfully generated by the PC itself.

Sometimes, different modulation types are employed. For example, continuous carriers and transmissions in F1B mode may be picked up from Russian transmitters, while the stations JXN a 16.4 kHz and GBZ at 19.6 kHz transmit frequency modulated burst signals from time to time. The unidentified stations at 15.8 kHz and 17.8 kHz appear to transmit that type of signal only. GBZ undoubtedly has the largest repertoire of modes: apart from MSK and frequency modulated burst signals it also transmits the odd pulse patterns that look like tiny fish or garlands.

In the GUS states, time signals are transmitted at fixed times on frequencies between 20 kHz and 26 kHz. These transmissions follow a fairly complex schedule for several stations, of which RJH69, RJH77 and RJH63 are the easiest to receive. At the frequencies that can be still be received with an ordinary soundcard (20.5 kHz and 23 kHz) only continuous carriers are transmitted (with the exception of RJH63).

Since the dismantling of OMEGA the Russian ALPHA is the only active navigation system left. ALPHA uses 11.905 kHz, 12.649 kHz and 14.881 kHz. Its signals consist of empty carriers with a duration of 3.6 seconds, which are far less conspicuous on the spectrograms than the white bands caused by MSK signals.

Interference

The VLF range is infested with interference from electrical appliances like switch-mode power supplies, computer monitors, TV sets, electromotors, gas discharge lamps and PCs. The best known 'headache' is the 15.625 kHz electron beam deflection frequency used in TV sets. Electromotors generate interference with a load and speed dependent frequency. Configuration commands for the high-voltage grid (electricity distribution system) are probably the cause of burst-like pulses between 17 and 18 kHz observed at the author's location. These bursts occur with different intensities and always last 20 seconds.

The PC used for the receiver system will also add a fair amount of interference. The frequencies will, of course, depend on the model and make of the PC, and they can be pinpointed by short-circuiting or disconnecting the antenna and then looking at the spectrum. It is safe to assume that all signals remaining in the spectrogram originate from the PC.

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More on VLF reception:
www.lwca.org

Corrections & Updates

Audio Combiner

A 4.7-µF electrolytic capacitor should be connected between R17 and ground. The + terminal of the capacitor is connected to R17. The same applies to R18, R19 and R20.

60-dB LED VU Meter

Due to a scaling error, the lower part of the circuit diagram is not visible. Components C5 and R7 should be connected to ground. The connections for S1 and S3 are on 3-way headers. The pole connection is at pin 3, not 2 as expected. Junction D21-C6-IC3 is erroneously labelled '+5V'. A suggested label is 'V+'.

Light Mixer Panel

The parts list on page 48 should be modified to read IC23,IC24 = CNY74-4.